EXPLOSIVE ORDNANCE DISPOSAL

COPY NO. 68

PICATINNY ARSENAL TECHNICAL MEMORANDUM 1667

FEASIBILITY STUDY

ON

EOD APPLICATIONS FOR LIQUID NITROGEN

LT. ROBERT R. VENNELL

JUNE 1965

AMCMS CODE: 5665 12 549

DEPT OF ARMY PROJECT NO: 1W 523801A583

U. S. ARMY
EXPLOSIVE ORDNANCE DISPOSAL CENTER
PICATINNY ARSENAL
DOVER, NEW JERSEY

PICATINNY ARSENAL TECHNICAL MEMORANDUM 1667

FEASIBILITY STUDY

ON

EOD APPLICATIONS FOR LIQUID NITROGEN

BY

LT. ROBERT R. VENNELL

JUNE 1965

REVIEWED BY: David R Wright
Acting Chief, R/D Division, U.S. Army EOD Center

APPROVED BY: Henry W Stupakewicz
Acting Chief, U.S. Army EOD Center

AMCMS CODE: 5665 12 549
DA PROJECT NO: 1W523801A583

U. S. ARMY
EXPLOSIVE ORDNANCE DISPOSAL CENTER
PICATINNY ARSENAL
DOVER, NEW JERSEY

ABSTRACT

A test program was conducted by Harvey Aluminum, Inc., Torrance, California, to develop a new means of inactivation of munition components by means of cooling to cryogenic temperatures. The cooling medium used was liquid nitrogen at a temperature of -320°F. Three fuze assemblies: the M562, the M524, the M509 and their elements were tested. While some success was achieved with the mechanical elements of timing fuzes (M562 and M524), where almost 90% were rendered immobilized, liquid nitrogen had little effect on detonator sensitivity, piezo electric crystals, and carbon bridge type electric detonators.

TABLE OF CONTENTS

I

CONCLUSIONS

It is concluded that although the cryogenic temperatures show fairly favorable deactivation of certain types of mechanical fuzes, the overall disadvantages of this procedure coupled with the limited availability of cryogenic materials, especially in the field, preclude it from further consideration by the EODC at this time.

The deactivation of various detonators, piezo crystals, and carbon bridge circuits was completely negative. Cryogenic temperatures are of no value in these areas.

II

RECOMMENDATIONS

It is recommended that no further work be done in this area at the present time due to overriding disadvantages. The deactivation of certain specific mechanical fuzes is, however, feasible and could be investigated at a more propitious time.

III

OBJECTIVE

The objective of this work was to develop a new approach in neutralizing unexploded ordnance. The approach was to consider the characteristics of liquid nitrogen and its capability due to extreme low temperature (-320°F) to immobilize, neutralize, or otherwise affect the performance qualities of munition components.

IV

BACKGROUND

Under the QDRI program, Problem 33 (Mechanical Trepanning), a proposal was received from Harvey Aluminum, Inc., Torrance, California, suggesting the use of liquid nitrogen for neutralizing unexploded ordnance. The scope of work for the proposed contract was prepared and eventually a single source contract was awarded to Harvey Aluminum to study the effects of liquid nitrogen on explosive components and, if feasible, to develop a concept for a portable liquid nitrogen kit for EOD.

V

CONCEPT

It was considered that extremely low temperatures (cryogenic) might have the capability of immobolizing, neutralizing, or otherwise affecting the performance qualities of munition components. This was a new approach to Explosive Ordnance Disposal Procedures and several factors contributed to the idea. Most fuzes are designed for low range temperature limits much higher than cryogenic temperatures. The extremely low temperatures would have various, hopefully favorable, effects on fuze components. For example, most lubricants solidify at higher than cryogenic temperatures and due to dissimilar metal construction, differential contraction of these parts tends to cause warping and constriction in close fitting mechanisms.

Liquid nitrogen (boiling point - 320°F) was selected as the prime medium for attaining cryogenic temperatures. There were several reasons for this choice. Firstly, liquid nitrogen is relatively plentiful and its cost is significantly less than other liquid gases. Secondly, it is relatively inert. Thirdly, it was felt that the - 320°F temperature it provides would be sufficient to carry out the study.

VI

PROCEDURES USED

See Appendix A, Report No HA-2144, "Summary Report Deep Freeze Program for Explosive Ordnance Disposal", Section IV, Report Text.

VII

RESULTS

See Appendix A, Report No HA 2144, "Summary Report Deep Freeze Program for Explosive Ordnance Disposal", Section III, Summary.

VIII

EVALUATION

While the results achieved were not 100% as hoped in the area of fuze deactivation, almost 9 out of 10 fuzes (M562 and M524) were rendered safe. This was accomplished with the fuze in its most hazardous condition i.e. nothing stopping it from functioning once the pins were removed. Although the EODC decided to cancel the project at this time, this approach to fuze inactivation shows some promise for further investigation in the future.

However, the results achieved on the lessening of detonator sensitivity, piezo crystal output, and carbon bridge type electric detonators were completely negative. These areas show no promise of cryogenic temperature deactivation.

HARVEY ENGINEERING LABORATORIES
TORRANCE, CALIFORNIA

PREPARED BY A. E. Joneikis DATE 6 May 1965

CHECKED BY H.W. Euker DATE 6 May 1965

APPROVED BY F. E. Anderson DATE 6 May 1965

REPORT NO. HA- 2144

SUMMARY REPORT DEEP FREEZE PROGRAM FOR EXPLOSIVE ORDNANCE DISPOSAL

CONTRACT NO. DA-28-017-AMC-1114(A)
PROJECT NO. 1W523801A583
OMS CODE NO. 5665.12.54900.05

For
Procurement Operations Division, SMUPA-PB1
Picatinny Arsenal
Dover, New Jersey

6 MAY 1965

HARVEY ENGINEERING LABORATORIES
for Research and Development
a division of
HARVEY Aluminum
GENERAL OFFICES TORRANCE CALIFORNIA

APPENDIX A

Copy No.

TABLE OF CONTENTS

I. ABSTRACT

A test program aimed at inactivating fuzes by means of cooling to cryogenic temperatures was conducted. The cooling medium used was Liquid Nitrogen, which, therefore, limited cooling to -320°F. Three fuze assemblies; the M562, the M524, the M509 and their elements were tested. While success was achieved with the mechanical elements of timing fuzes (M562 and M524), where almost 90% were rendered inactive, Liquid Nitrogen did not produce sufficient cooling to do more than lessen sensitivity of detonators and had little deleterious effect on the piezo crystal and carbon bridge type electric detonators.

II. INTRODUCTION

Although it is difficult to document the first application of the fuze due to its long history of use, we all know that the early Chinese used simple fuzes to ignite fire crackers and rockets, long before the existence of projectile and bomb fuzes as we know them today. These early fuzes, and the same basic type are still in use, were ordinary tubes or cords filled with combustible material and simply served to ignite a high burning-rate material.

Since those days, fuzes have become consistantly more sophisticated until, at this point, they are complex mechanisms which must satisfy numerous requirements and serve several functions. Modern fuzes must not only initiate the main charge, but do so at the correct time and at the correct distance from the target. They must also provide safety in rough handling, withstand severe environments for long periods of time, yet perform all these functions with a high degree of reliability.

Unfortunately, even with all the precautions used in modern design and careful quality control, occasional "duds" are still experienced. Even more serious is the fact that these "duds" all too often occur in extremely precarious areas. Ammo dumps, fuel dumps, expensive and large buildings in the center of heavily populated cities, are examples of just a few of these critical areas. Under these conditions, it is obvious, then, that these "duds" cannot be simply destroyed. They must be defuzed and removed. Explosive Ordnance Disposal personnel are then saddled with the responsibility of accomplishing this feat. It goes without saying that this type of work can present quite a hazard. Conclusive evidence of the hazard involved in this type operation was demonstrated by the numerous catastrophes that occured to E.O.D. personnel during de-fuzing of "dud" bombs during World War II.

Engineers at Harvey Engineering Laboratories, being aware of these problems through years of association with fuzes, "duds" and misfires, submitted an idea, via a QDRI proposal, for safely rendering "dud" fuzes inactive.

II. INTRODUCTION (cont.)

Several factors contributed to this idea. We knew, for instance, that most fuzes are designed to withstand temperatures ranging from about +165°F to -65°F. We also knew of the deleterious effects these temperatures had on the various parts, particularly at cold temperatures. Most lubricants, for example, solidify at -65°F, and differential contraction of dissimilar material tends to cause warping and constriction in moving parts. With these facts in mind, Harvey proposed that super-cooling, to cryogenic temperatures, might have the desired effect of safely inactivating a normal fuze.

Liquid Nitrogen (boiling point of -320°F) was suggested as the prime medium for super-cooling. Several valid reasons supported this decision. One, LN_2 is relatively plentiful; secondly, its cost is significantly less than other liquid gases; thirdly, it is inert and hence, safe (except when in contact with certain rare metals); and last, it was felt that the -320°F would be sufficient to at least constrict the mechanical elements of most fuzes and certainly have some effect on sensitivity of explosive elements.

The report contained herein, therefore, describes Harvey's efforts in a program aimed at proving that cryogenic temperatures can render fuzes, particularly "duds", inactive.

III. SUMMARY

This report constitutes our final report on Deep Freeze for Explosive Ordnance Disposal, and describes our efforts to render fuzes and their elements inactive through cooling to cryogenic temperatures. Since this contract restricted the use of any other liquid gases except Liquid Nitrogen, the coldest temperature achieved was -320°F, its boiling point.

Four distinctly different type fuzes were government furnished for test purposes, the M562, the M524, the M509, and the M514VT Fuze.

It was found, early in the program, that although some degradation in sensitivity occured in explosive elements when cooled to -320°F, it was insufficient to render them safe.

Approximately 86% of the M562 Fuzes tested were mechanically inactivated by application of LN_2.

Approximately 87% of the M524 Fuzes tested proved susceptible to mechanical constriction at -320°F, and thus were rendered safe.

Both the Barium Titanate crystal (power source) and the carbon bridge M48 Detonator, used in the M509 Fuze, could not, except in one instance, be inactivated at -320°F.

Inasmuch as no drawings, instructions, or data were received regarding the M514VT Fuze, this unit was not tested. We did, however, just prior to notice to terminate the contract, disassemble several live fuzes. Had time permitted, we could have set up psuedo "dud" conditions and tested the mechanical elements. The electrical and electronic elements, on the other hand, could not be tested. Lack of information relative to voltage, power output, check points, and general electronic characteristics precluded any evaluation of this section of the fuze.

Recommendations for follow on, using Liquid Helium as a cooling medium (boiling point -452°F) are included in this report.

IV. REPORT TEXT

Our initial efforts on this contract were directed toward developing a Liquid Nitrogen transfer system to permit remote discharge of the liquid at a controlled rate through a nozzle. In order to hold expenditures to a minimum, a modest appearing but highly effective system was produced. This system permitted discharge of LN_2 either through one or multiple nozzles at a distance of approximately 15 feet from the storage tank. (This distance was considered the minimum safe distance for testing detonators and ignition trains). Some difficulty was first encountered on determining the correct diameter nozzle in the multiple nozzle arrangement, (each needed to be a different size to provide equal flow), but this was effectively solved and the same basic unit served satisfactorily for all tests conducted.

A holding and remote firing fixture was designed concurrently with our work in determining an effective nozzle arrangement. This rugged, heavy, fixture was designed to permit easy application of the LN_2 with minimal heat transfer yet withstand repeated detonation without structural damage.

During the interim in which the test fixture was being fabricated, several each of M562, M524, and M509 Fuses were assembled, from loose parts, disassembled and studied. This effort was conducted as part of our analysis to determine both the areas most susceptable to failure, and how to simulate a possible "dud" condition. As a result of this study, several mock "dud" conditions were established and set up. These simulated "duds" were purposely made extremely sensitive in order to provide the worst possible conditions and thereby rule out any possibility of misleading, and hence, false security. It was not until after these mock "dud" conditions were established, that we received "Notes on Development Type Material" for these three fuses. These "Notes", however, merely indicated in general how the units functioned, so our study to establish psuedo "dud" conditions still would have had to be performed

Upon completion of the holding and actuating fixture, a series of tests were conducted on various stab type detonators and stab detonator-lead combinations.

IV. REPORT TEXT (cont.)

These elements were placed in a fixture and cooled down to very nearly the boiling point of Liquid Nitrogen (temperature recorded by a thermocouple in conjunction with a calibrated temperature recorder). Once the temperature was stabilized, the fixture was energized, stabbing the detonators at varying energy levels (see data sheet).

These tests showed that the -320°F temperature will not prevent function of a stab type detonator with a high energy firing pin. The sensitivity is, however, reduced by the cold, since one M47 detonator did not function when subjected to a stabbing action of low energy (but above the minimum level established for the detonator). Penetration of the M47, that did not fire, was approximately .070 inch. To assure that the detonators being tested were not sub-grade, another M47 from the same lot was subjected to the same low energy stabbing, at room temperature, and it functioned normally. Inasmuch as the energy level of the stabbing systems on the unit tested was significantly higher than the minimum established level, all subsequent tests for the various type detonators were conducted at high stabbing energy levels.

As a result of the negative findings in these tests, we directed our attention to the fuze mechanisms.

In order to present a mock "dud" situation which might conceivably be encountered by a demolition team, we had to make a number of assumptions: We established a hypothetical case where the fuzes would be armed by ballistic setback and/or spin and would be inadvertantly restricted from further operation during projectile flight. It was further hypothesized that, upon impact, the cause of operational restriction was removed and that even the slightest movement could effect actuation.

IV. REPORT TEXT (cont.)

This pseudo "dud" situation was effected in the following manner:

M562. We magnetically moved the Arbor Lock out of engagement with the slot in the spring driven Arbor. (This function is performed centrifugally during firing). The Escapement Pallets, which lock the Escapement and move radially out of engagement under centrifugal force, were then manually released, allowing the movement to actuate. Movement was terminated when the slot in the Arbor rotated to a point where the Arbor Lock could no longer drop back and restrict rotation. The Setting Pin was removed and replaced with a long Interference Pin. (The Head diameter was machined to permit access to the Pin from the outside). (Refer to Fig.2) This Interference Pin was then placed in front of the Safety Disc lug to restrict rotation. Inasmuch as the Safety Disc is rigidly attached to the Arbor, Safety Disc restraint precludes Arbor rotation. Two spacers were then placed in the pallet riding slots located in the lower plate, after the pallets were disengaged, thus forming a mechanical block to re-engagement of the pallets and Escapement. When in this condition, the fuse is fully armed and restricted from operation solely by the Interference Pin, which is accessable for removable from the outside. When a steady state cold temperature is reached, this Pin is removed and the fuze is tapped, tipped and jostled to enhance starting.

To eliminate the introduction of another variable, the movements in this series of tests were demagnetized prior to test.

M524. In this fuze, we rotated the set-back operated segment clockwise, until its shoulder almost contacted the Interfering Trigger tip.

IV. REPORT TEXT (cont.)

After rotating the Trigger clockwise to free the Segment, the Segment was further rotated until the Link Stop and Lever were free to pivot, clearing a path for the spring loaded Timing Mechanism to position the normally out of line Detonator to an in-line position. The Detonator (encased in the Rotor) was then rotated back to the pre-armed out of line position and was restrained from arming solely by the "L" shaped holding Lever which was also returned to its unarmed locking position. The mechanism was assembled into the body, the safety wire inserted through the body and into the pull wire slot of the movement and in this way served as an Interference Pin for the holding Lever.

This is an intricate operation requiring considerable dexterity and a special long thin pin to preclude inadvertant actuation before the pull wire is positioned. In this condition, once the pull wire is removed, the only element preventing rotor rotation is the holding Lever, which is in turn easily displaced by the high spring force of the mechanism. The safety wire is removed at the cold temperature after which the fuse is tapped and jostled to assist actuation.

Our initial tests on the M562 Fuze proved to be very encouraging. Several fuzes were cooled to very nearly -300°F, (see typical curves). When a steady state condition was reached, their respective release pins were immediately extracted to see if they would function. These fuzes proved to be inoperative at this temperature and would not actuate even when subjected to jostling and tapping until they warmed to temperature approaching -100°F.

The nozzle arrangement was slightly modified upon the conclusion of these initial tests to enable attainment of lower temperatures in less time. This modification proved successful since temperatures approaching -320°F were achieved in about one half the time. Even quicker cooling is possible but only at high cost and undue sophistication.

IV. REPORT TEXT (cont.)

Results in this next series proved to be erratic as indicated on the data sheet. Some units were stalled so completely that every external attempt to force starting was futile, while in other instances, the fuzes started immediately after being tapped for the first time.

A critical study of the M562 was made after the first two units operated at cryogenic temperatures. This investigation disclosed that considerable looseness of fit was evident throughout the Movement. Since the greatest shrinkage we can expect through differential contraction (between steel and aluminum) is approximately .0027 inches/inch, and less for other materials, it was evident then that inactivation by means of cryogenic induced constriction would not be easy.

The following are some interesting observations that were made during this last series of tests.

1. One unit (M526) would not start throughout the temperature range even after being subjected to tapping and jostling. This mechanism was tested at ambient temperature and proved to be operative immediately prior to the cooling test.

2. This same unit was disassembled and the reason for failure to function was not ascertained. We, therefore, reassembled the Movement into a fuze body and cooled the fuze to a temperature of -315°F. At approximately -120°F, the Movement would intermittently start, and stop (after being subjected to small shock loads). When the Movement finally actuated, the Torsion Spring loaded Firing Arm passed the firing notch in the Timing Disc Assembly. The Firing Pin, as a result, was not released and could not actuate.

This test was repeated and actuation began at a lower temperature of -270°F and the Firing Arm again failed to enter the firing notch. We then repeated the test at ambient temperature. This time the unit functioned in a normal manner, i.e., the Arm moved into the notch and the Firing Pin actuated.

IV. REPORT TEXT (cont.)

In order to determine whether indiscriminant locking action might be a function of variation in assembly, several Movements were partially disassembled and twist was introduced between the sandwiched Plates (to introduce distortion if possible) and then they were reassembled. Tests were conducted with both clockwise and counter-clockwise twist induced in the Movements. This action, however, seemed to have no discernable adverse effect on function.

A new method of testing was then instituted. All previous tests were conducted with the Movements enclosed in fuze bodies. In this new series of tests, we simply immersed the Movements in LN_2 until a temperature of -320°F was reached. They were then extracted and manipulated, with a probe, in an attempt to determine which component or components were responsible for locking the mechanism. This manipulation was initially conducted in a cold box and hence dry atmosphere, to preclude frosting. This procedure was later abandoned in favor of placing the cold Movements under infra-red heat lamps, since warming action took too long with the former. Very little frost collected, at a very slow rate, while under the heat lamps.

As in our previous tests with enclosed Movements, no set pattern could be established. Some functioned immediately, even when we allowed frost to accumulate, while others could not be induced to run even when we applied force to the Escapement. We also found in some cases, that even though the timing mechanism operated immediately, the Firing Lever would become bound up and would fail to enter the Timing Disc notch, resulting in failure of Firing Pin actuation.

Note that some Movements were re-tested several times to ascertain whether conditions would repeat. (Refer to Data Sheet). Although some repeatability was determined, there were sufficient variations even in the same movement - subjected to the same conditions - so as to preclude establishment of a set pattern.

IV. REPORT TEXT (cont.)

One of the units that displayed a tendency for Firing Lever "Lock Up" was disassembled and checked for fit. Sufficient clearance was found in the bearings so that binding should not have occured (.0026 at the top, and .0018 at the bottom). The unit was, nevertheless, reassembled sans all moving parts except the Firing Lever and then immersed in LN_2 and cooled to -320°F. This time the Lever did not bind.

Immersion tests were continued on the M562 and M524 to determine the effect of repeated cycling through the temperature range with the following results:

Six M562 Fuze Movements and three M524 Fuze Timers were alternately cooled and warmed. They were immersed in Liquid Nitrogen and then placed under heat lamps where they warmed at the rate of approximately 30°F per minute. All were tapped, jostled and shaken during the warming cycle.

All of the M562 Movements operated at progressively lower temperatures as immersion was repeated and all eventually operated while still immersed in Liquid Nitrogen. However, in three of the six cases, the Firing Pin did not advance because the Firing Arm remained locked while the slot in the Timing Disc rotated past the normal firing positon.

Three of these M562 Timing Mechanisms had been previously tested while encased in the fuze body and their temperature reduced to approximately -315°F. One had operated three successive times at this temperature. Before this mechanism was immersed in Nitrogen, the bearing hole for the Balance Wheel was packed with grease from another fuze. The first time it was immersed it was induced to operate at approximately -298°F by manipulating the Balance Staff and the Balance Wheel. The second time it was immersed it operated at approximately -230°F after being jostled, tapped and shaken during the warming cycle. The third time it operated while immersed in Liquid Nitrogen but the Firing Pin did not advance. It is to be noted that the Firing Pin in this unit did not advance while encased in a fuze body during any of the three tests in which the Timing Mechanism functioned at -315°F.

IV. REPORT TEXT (cont.)

Another M562 that had been previously tested as a complete unit had operated once at -22°F. In the next test it did not operate until it had reached ambient temperature and was being disassembled. In a subsequent LN_2 immersion test, using the Movement only, it operated normally while still in the liquid.

A third M562 that had initially failed to operate until a temperature of -68°F had been reached, later functioned twice at -315°F. The Timing Mechanism was then removed and operated the first time it was immersed in LN_2, but the Firing Pin did not advance.

Three M562 mechanisms, that had not been previously tested, operated at progressively lower temperatures as immersion in Liquid Nitrogen was repeated. One operated at -170°F, then at -320°F; another at -170°F, -215°F, and -320°F (the Firing Pin did not advance in this one); the third unit operated at -125°F, -200°F, -245°F, and finally -320°F.

Of the six mechanisms tested, only one operated below -300°F the first time it was tested. This unit had twice previously been cooled to -315°F as a complete fuze and the Firing Pin did not advance at this temperature.

The three M524 Fuze Movements that were immersed in Liquid Nitrogen did not exhibit a tendency to operate at progressively lower temperatures and none of them operated immediately after removal from the Nitrogen. One operated at -215°F and -245°F, another operated twice at -230°F and the third operated at successive temperatures of -200°F, -305°F, -230°F, -215°F and -230°F.

We can only conclude, as a result of these tests, that a multiplicity of factors govern susceptability to constriction. Three primary factors are:

1. Variations in tolerances of components,
2. Variations in assembly (twist, staking and tightness of screws) and,

IV. REPORT TEXT (cont.)

3. Obvious presence of grease on outer surfaces on some units and little or none on others.

A series of low energy, nondestructive, tests of the Lucky assemblies used in conjunction with the M48 Detonator (M509 Fuze) were then conducted. These tests consisted of subjecting these assemblies to an impact energy of one foot pound and measuring the electrical energy output of the crystal in terms of voltage amplitude and time to decay. The same crystals were tested at both ambient temperature and -320°F.

An oscilloscope was electrically connected in parallel with a Lucky assembly and an 1100 ohm resistor at the time the one foot pound of energy was applied (the resistance simulated the minimum resistance of an M48 Detonator). The quantity of Lucky assemblies available was not sufficient to establish precise quantitative results but a pattern was quite evident. The pattern detected was that Luckies produce considerably higher voltages at -320°F than at ambient, but decay to zero in slightly less time. At cryogenic temperature the average maximum voltage was 6.7V and the average time to decay was .875 milliseconds. At ambient temperature the average maximum voltage was 5.3V and the average time to decay was .95 milliseconds.

The crystals is these assemblies showed no signs of deterioration from repeated cooling but the plastic insulation cracked in some cases. These Luckies were subsequently used to detonate M48 Detonators and functioned normally.

In the high energy tests of the Lucky assemblies, an impact force of approximately 67 foot pounds was applied. This force was sufficient to destroy the assembly and assure maximum output from the crystal.

An M48 Detonator was electrically attached to the Lucky in each of these tests and three different combinations of temperatures were used; vis: the Lucky at ambient and the Detonator at -320°F, the Lucky and Detonator both at -320°F, and the Lucky at -320°F and the Detonator at ambient.

IV. REPORT TEXT (cont.)

The M48 Detonator fired, high order, with all three combinations of temperatures. In one of two tests, however, where both crystal and detonator were stabilized at -320°F the Detonator failed to fire.

Oscilloscope traces of the electrical energy output of two Luckies, one at ambient and the other at -320°F, with both units subjected to the same 67 foot pound impact energy, indicated a significantly different behavior between the two. While both reached a maximum voltage output of slightly more than 300V, the ambient temperature Lucky produced a rapid rise in voltage to 300V followed by an instantaneous decay to zero (the apparant point of destruction) within .11 milliseconds. The Lucky, at -320°F, on the other hand, initially produced current flow in the positive direction, almost immediately reversed to a negative direction, again reversed direction, crossing the zero point in .1 millisecond, then oscillated in an irregular sinusoidal pattern for an additional .21 millisecond until instantaneous decay to zero occured, at 150V positive (the point of destruction). The total energy output was higher at the cryogenic temperature.

To compare the energy necessary to fire an M48 Detonator at ambient temperature and -320°F, a .002 microfared capacitor was charged to 300V and the time from the capacitor discharge to detonation was measured. The Detonators selected for successive tests exhibited approximately the same internal resistance.

An oscilloscope was electrically connected in series with the capacitor and a detonator for current measurement. One of the leads was taped to the Detonator in a manner that would assure a break in the circuit to the oscilloscope at the moment of detonation.

With this setup, four oscilloscope traces were recorded photographically, two with the Detonators at 75°F and two with the Detonators at -320°F. The pictures were almost identical. All showed a maximum of 300V which decayed to approximately 20V in one microsecond and oscillated to zero in a total of 1.8 microseconds.

IV. REPORT TEXT (cont.)

The resistance in these Detonators was 4910, 4959, 5100 and 5230 ohms, respectively.

As a result of not receiving the necessary information to permit analysis of the M514VT Fuze and the subsequent establishment of test parameters, it was decided to disassemble and study a few of these fuzes. Three M514 Fuzes were carefully disassembled and the Detonators, Leads, Relays, and Boosters were removed. Inasmuch as no drawings, descriptions or instructional material was available, this was pretty much of a "Blind" operation, but was nevertheless successfully accomplished. A cutaway of an early model but similar VT Fuze, which was borrowed from a military museum, aided this effort.

After careful study, we finally were able to establish its operation and the sequence of events that occur during normal delivery of the fuze. One difficulty did, however, arise which is unlike that encountered with the other three fuzes tested. We had no means of ascertaining voltage or power output of the battery section; nor could we determine the characteristics of the potted electronic circuitry, all of which are necessary in order to establish if, or to what degree, this portion of the fuze is affected by cryogenic temperatures.

The mechanical portion on the other hand, albeit somewhat complex, was mastered to the point where we did establish methods of testing. We were in a position to test this portion, in a manner similar to that used on the Movement of the M562, when the completion date of the contract caused termination of work.

V. CONCLUSIONS

1. Although deep freezing with Liquid Nitrogen (-320°F) did not prove to be 100% effective in deactivating the mechanical and explosive elements of the various fuzes tested, it did provide a good measure of success; it was in the right direction and did come close to achieving the desired overall results. Because our tests indicated progressively higher incidences of success as temperature decreased, we can only conclude that deep freezing to the much colder temperature of Liquid Helium (-452°F), could very possibly achieve that desired goal of 100% effectivity. While we do not advocate Liquid Helium for universal use, we do feel that in specific critical instances, this mode of disarming might be "the only way" to meet this necessity.

2. Percussive detonators, while they do degrade somewhat in sensitivity at -320°F, the degradation is not considered sufficient to consider them inactive.

3. Of the fourteen new M562 Fuzes tested, two functioned almost immediately at, or near, -320°F. From this limited amount of testing, the percentage of fuzes firmly inactivated is approximately 86%. Of the two fuzes which started immediately, one failed to fire due to Firing Lever lock-up. If this latter failure were considered to be a safe inactivation, the percentage of M562 Fuzes rendered inactive would be approximately 93%. All fuzes were agitated, tapped and jostled after cooling to assure positive constriction.

4. Repeated cooling and heating the fuzes, after the initial test, caused the movement to operate at colder temperatures. Twenty-two repeat tests were conducted on the M562 to determine whether repetition would have any effect on function. Of the twenty-two tests, function occured almost immediately in fifteen cases. It would appear, therefore, that reliable inactivation can be expected in only 32% of fuzes in a repeat test. This should not be considered as a valid indication of successful inactivation of the M562, however, since repeat cooling and heating is not a practical situation and was merely performed in an attempt to determine why failures occured.

V. CONCLUSIONS (cont.)

5. Six new M524 Fuzes were tested at -320°F. One of these movements started at approximately -305°F. Two repeated coolings of the same fuze caused the unit to lock-up and be safe for a considerable length of time.

6. Eleven repeat tests were conducted on the M524 Fuze. All remained locked-up when the pin was extracted. One, however, was marginal and could be construed as being a failure. Of the fifteen tests conducted, new and repeat, one failure occured and one was marginal. If we consider both as failures, then approximately 87% of the M524 Fuzes can be considered susceptable to inactivation at -320°F based upon this limited number of tests.

7. The rotor of the M509 Fuze is not susceptable to lock-up at -320°F.

8. Both the M48, carbon bridge detonator and the Barium Titanate crystals appear to be impervious to -320°F, although in one case, the crushing of a piezo failed to fire an M48.

9. No tests were conducted on the M514VT Fuze as a result of lack of available information regarding the electrical and electronic portions of the fuze.

10. A portable kit for depositing LN_2 on fuzes was not designed or supplied, since -320°F (the boiling point of LN_2) is insufficiently low to assure 100% deactivation.

11. It is conceivable, and likely, that the pseudo "dud" conditions established by this contractor were far more sensitive than could actually occur under field conditions. If this be the case, it is equally conceivable that the application of the deep freeze principle to deactivation of fuzes, even at -320°F, was significantly more successful than it would appear from the data obtained.

VI. RECOMMENDATIONS

1. It is strongly recommended that Liquid Helium be used as a supplementary cooling agent, since it can reduce the temperature of fuzes and their elements to approximately -450°F.

2. Since some degradation in sensitivity of percussion primers occurs at -320°F, Liquid Helium at -450°F, may render these elements safe.

3. Inasmuch as both the M562 and M524 can be rendered safe (mechanically), in almost 90% of cases at -320°F, it would appear reasonable that 100% could be achieved at -450°F.

4. While we are not optimistic that the carbon bridge type M48 detonator can be defeated at -450°F (the resistance of carbon increases as the temperature decreases), we do feel that its power supply, i.e., the Barium Titanate crystal, can be defeated since it is reputed that its electrical output severely diminishes above this temperature.

While it is admitted that Liquid Helium is relatively expensive, and not quite as readily available as LN_2, we nevertheless feel that in specific instances, these deterring factors would be insignificant compared to the substantial gains which might be derived from its use where critically needed. As an example, what amount of time and money would the Government be willing to expend if a "dud" bomb, located in an Ammo or Fuel dump or, for that matter, an expensive bridge or building, could be safely and positively disarmed. We therefore, feel that while this mode of disarming does not appear to be practical for universal use, in some instances it could be the only feasible method.

VII. ILLUSTRATIONS

Figures 1 and 2 show the location of the thermocouples used to determine temperature. Figure 3 shows the nozzle arrangement (3 nozzles) and their approximate location with respect to the Fuze Body during cooling.

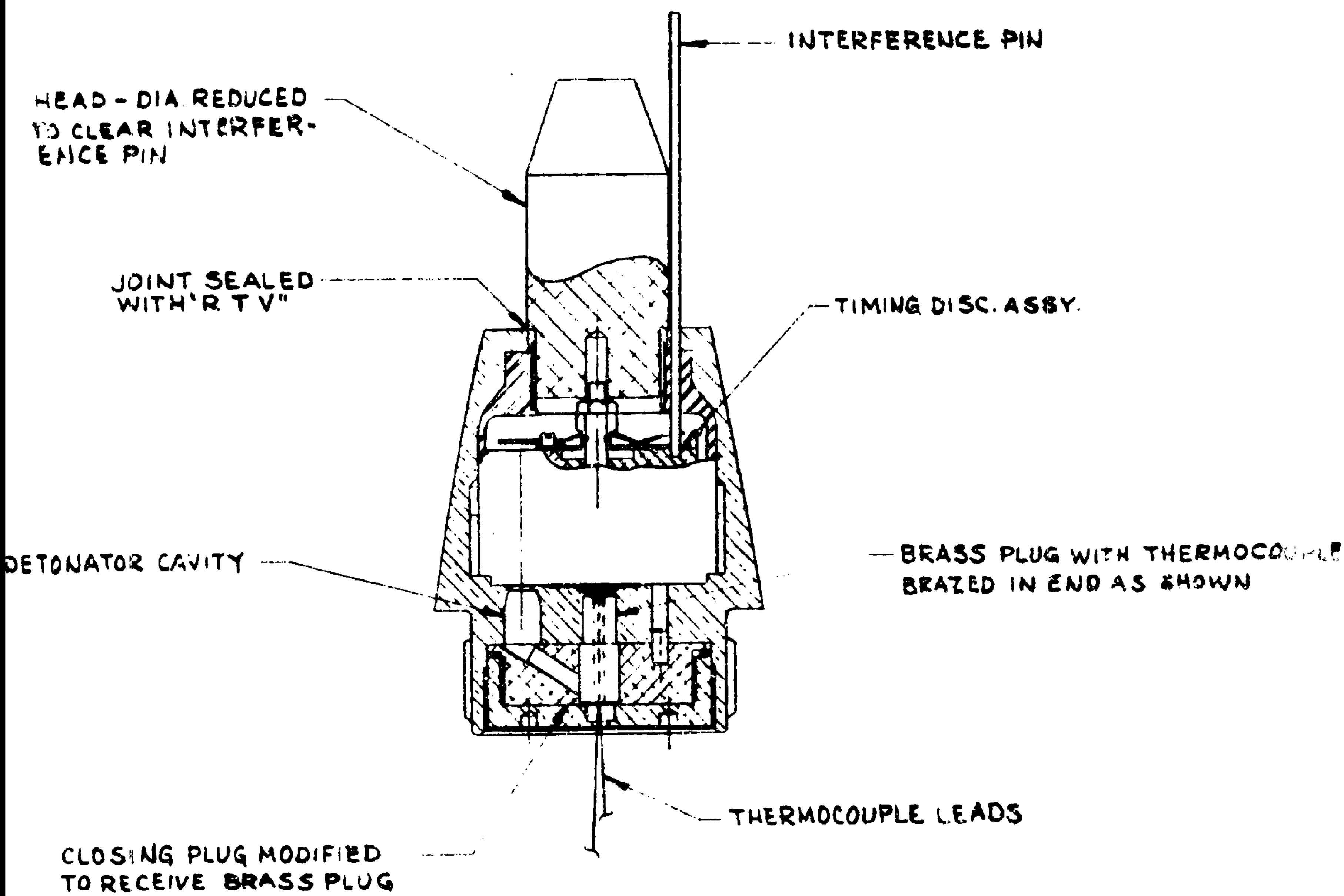
Drawing No. 1-11402 shows the detonator holding and actuating fixture used to test detonator and detonator-lead combination.

Drawing No. 1-11410 shows the fixture used to contain and actuate the Barium Titanate crystal both at ambient and at -320°F, in conjunction with the M48 detonator and oscilloscope.

Figure 4 shows the data obtained during detonator testing.

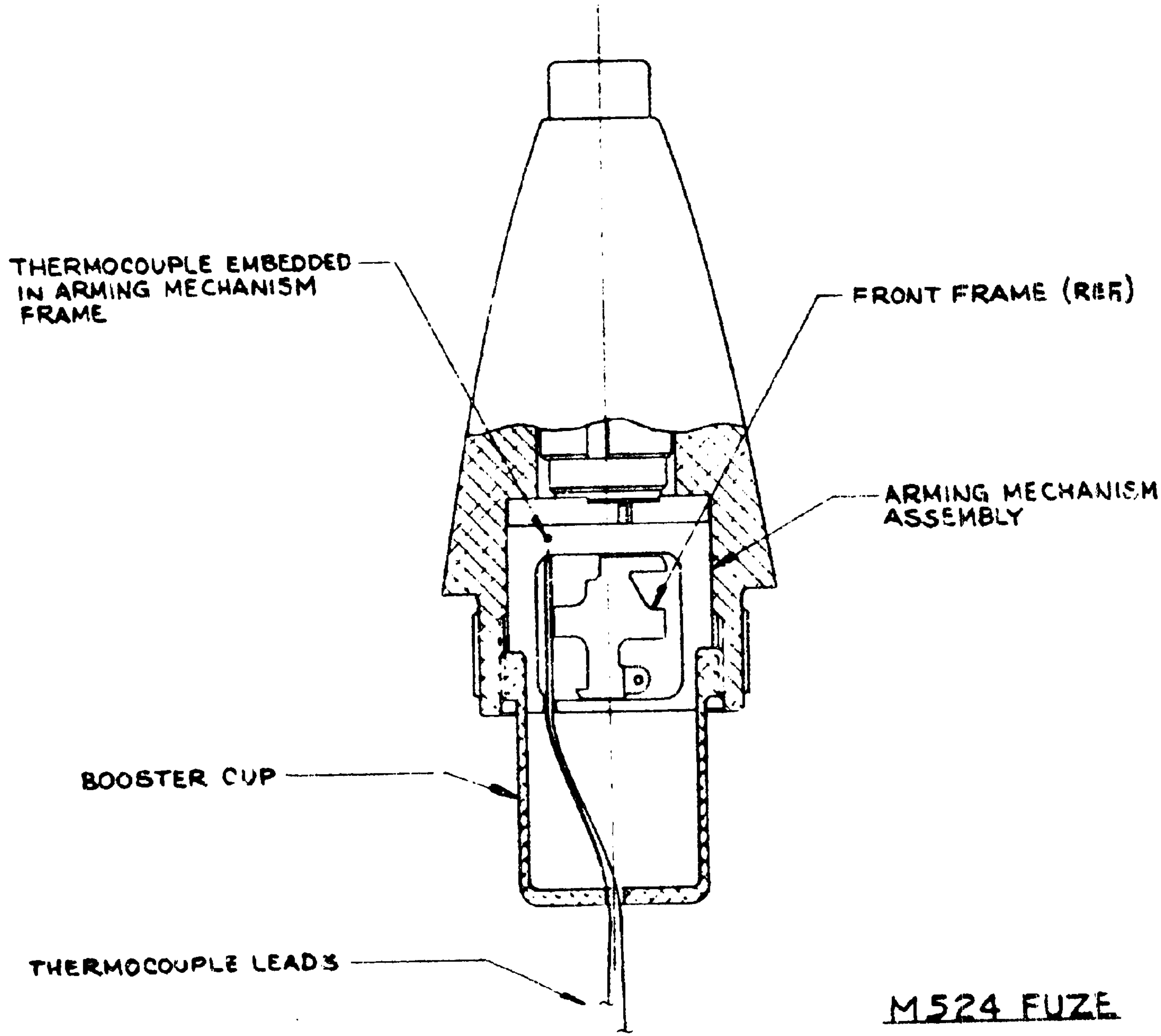
Figure 5 shows the data obtained in testing the M562, M524 and M509 Fuzes.

Figure 6 is a graph of temperature vs time of typical tests on the M562 and M524 Fuzes.



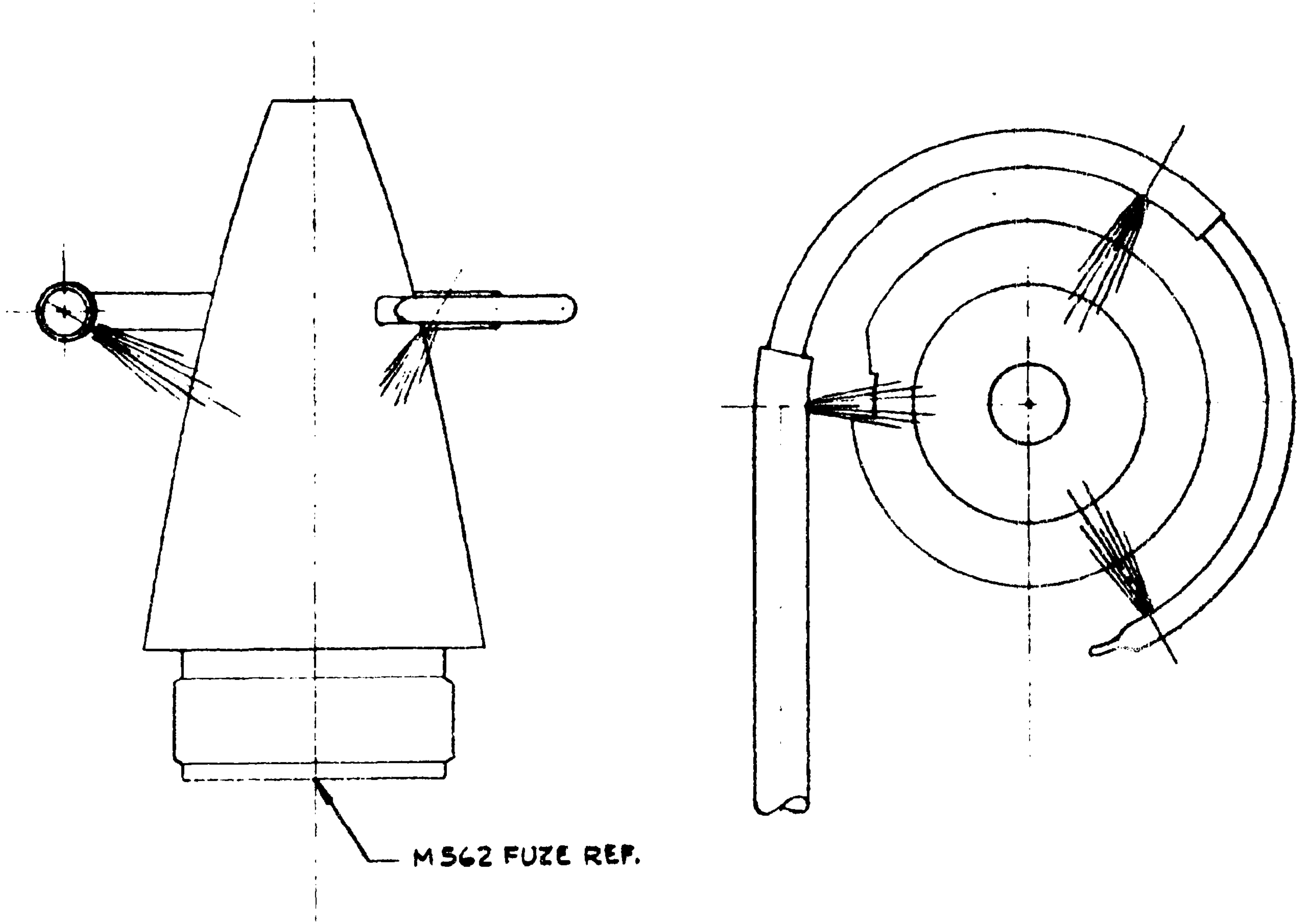
M562 FUZE

FIG. 1



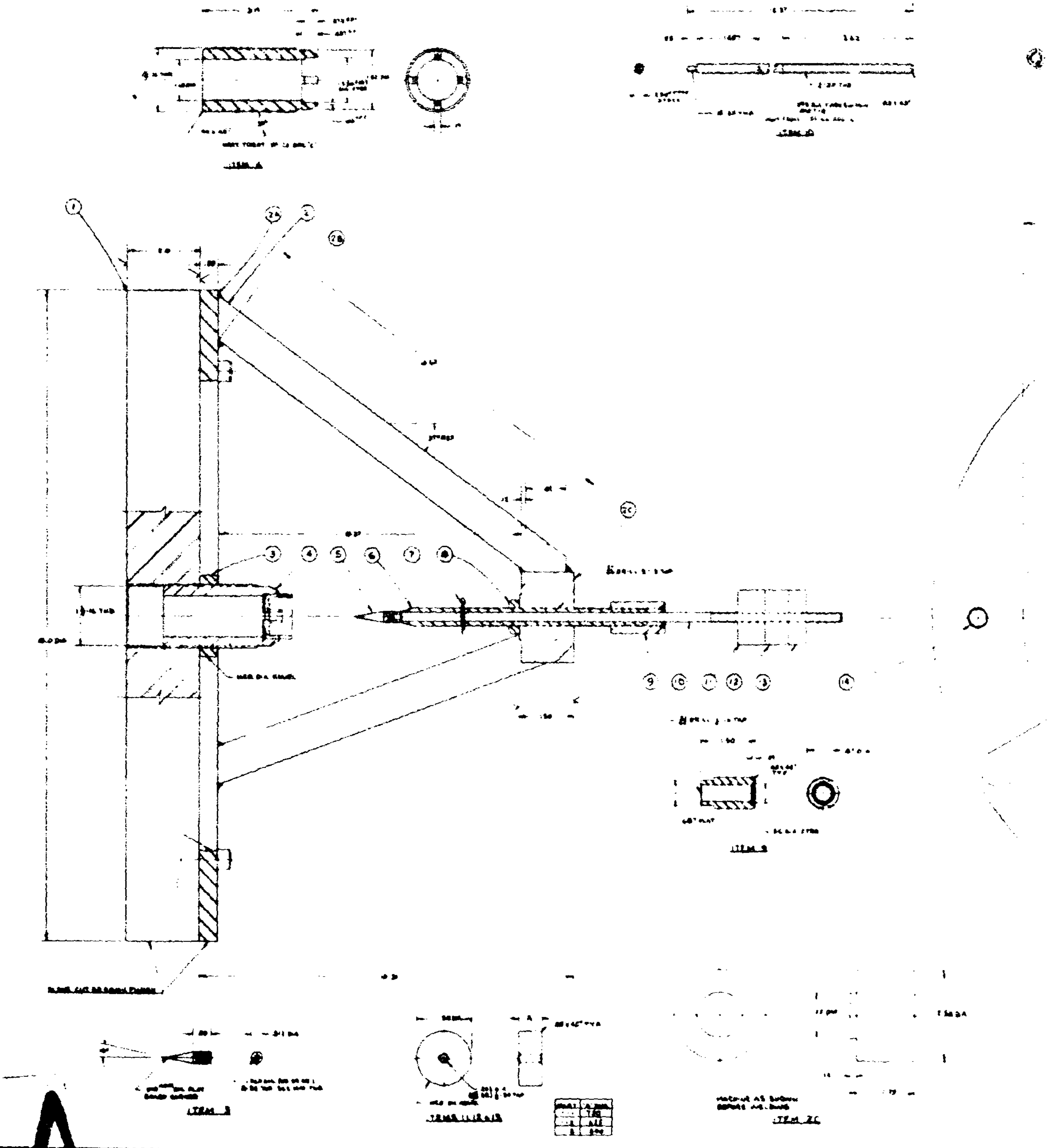
M524 FUZE

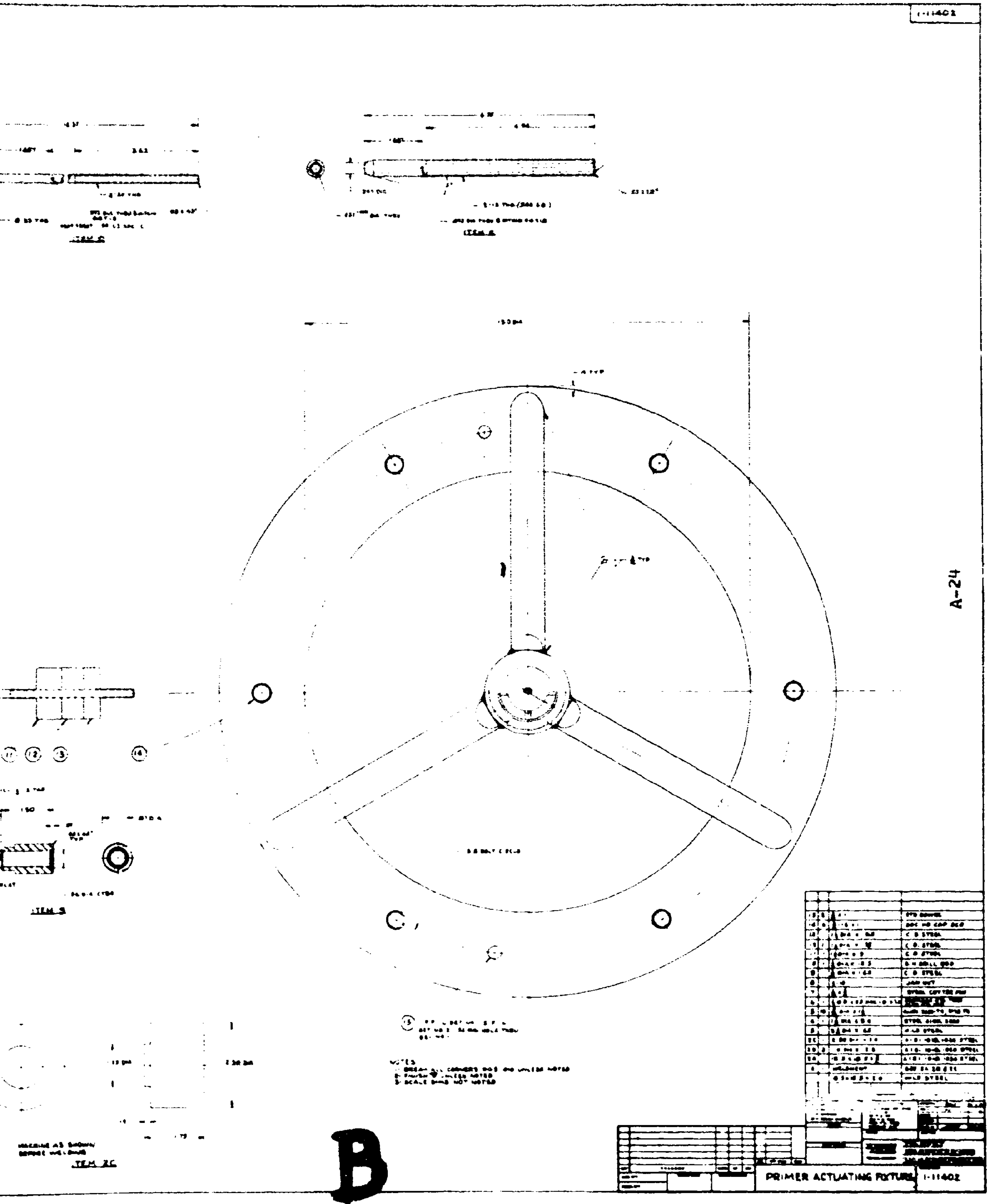
FIG. 2

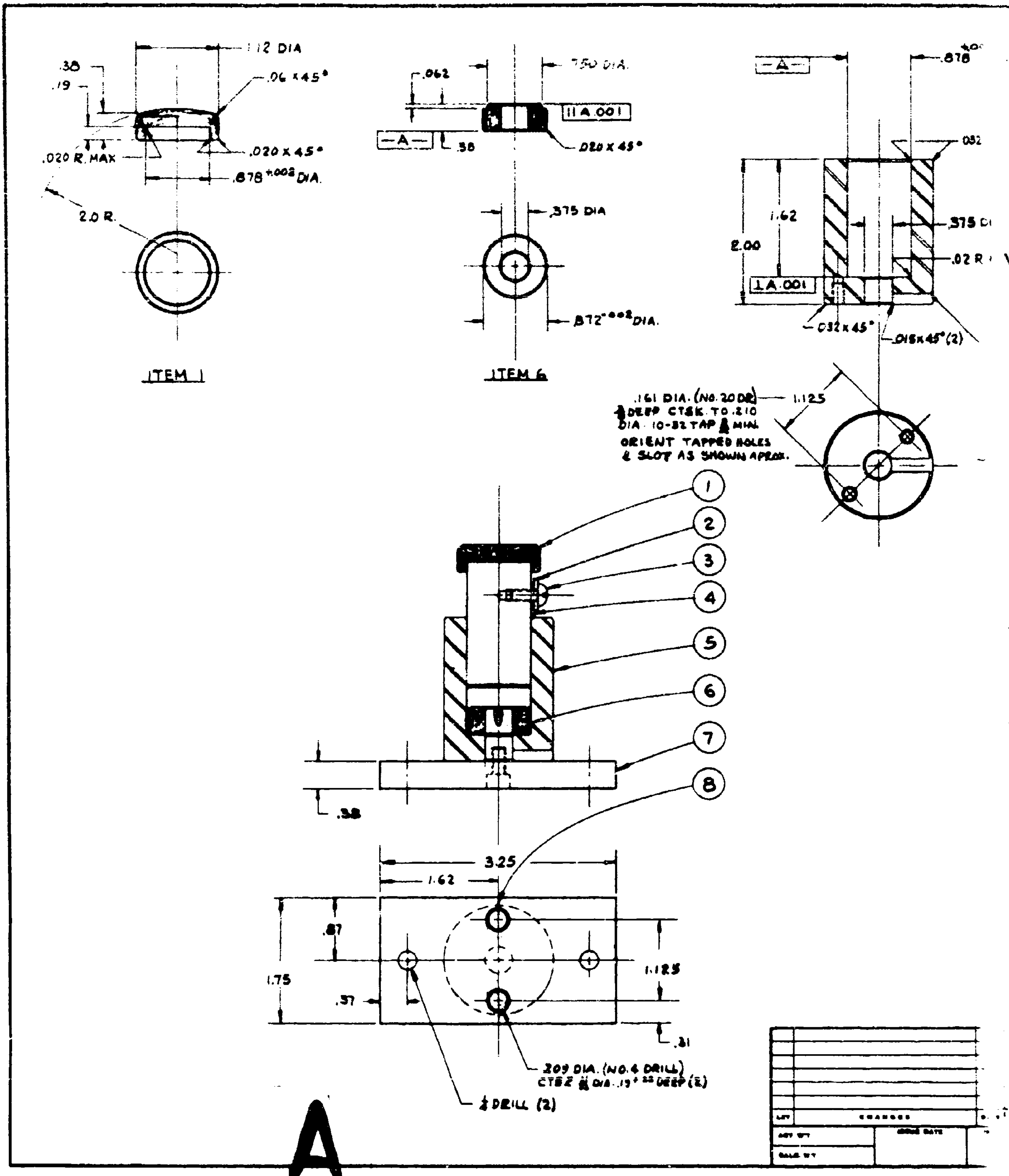


LIQUID NITROGEN NOZZLE

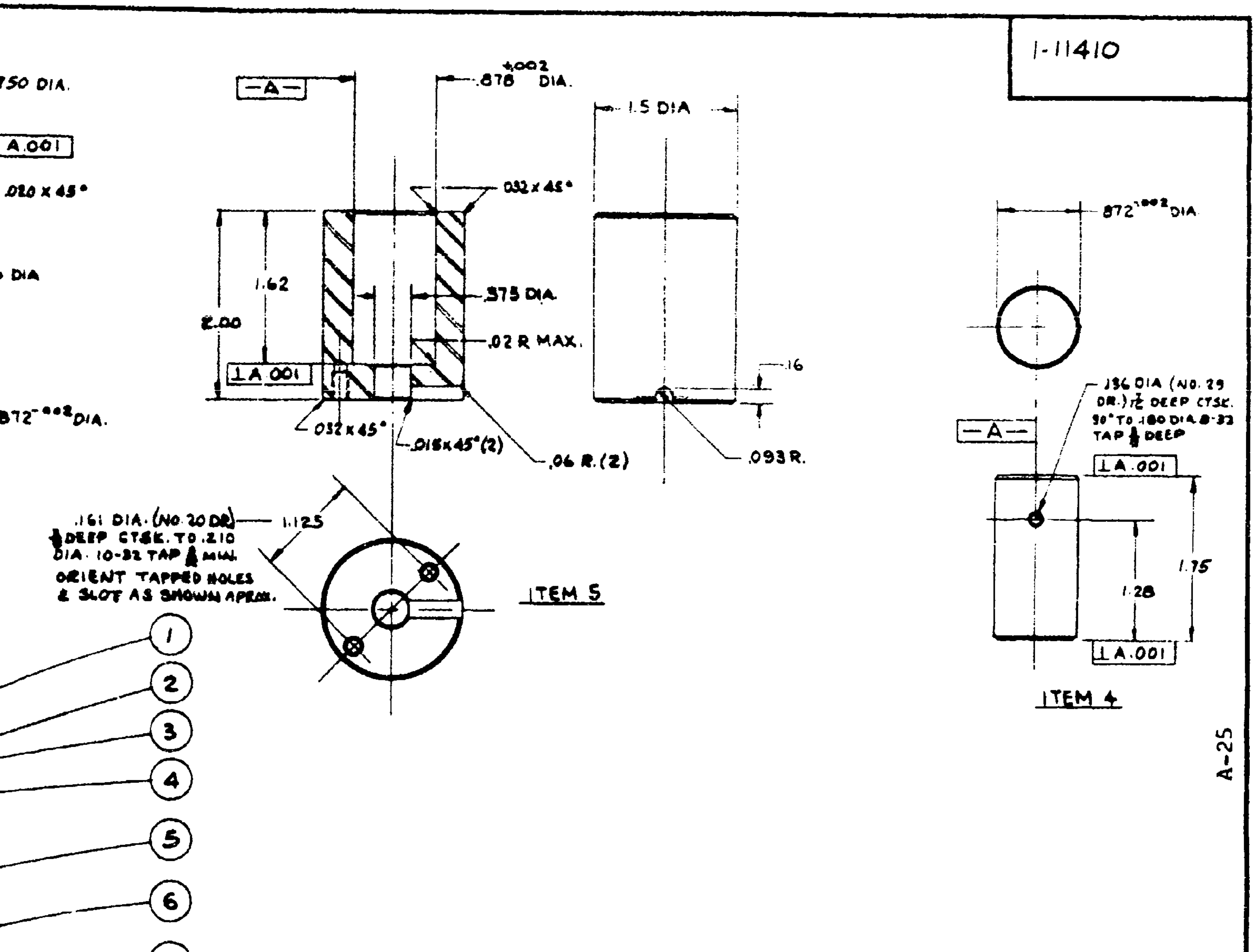
FIG. 3



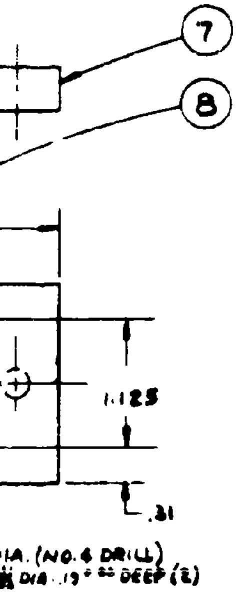

1-11402
ITEM 2C
NOTES
PRIMER ACTUATING FIXTURE
1-11402
B


1.12 DIA
.38
.19
.06 x 45°
.020 R. MAX
.020 x 45°
.878 +.002 DIA.
2.0 R.
ITEM 1
.062
.750 DIA.
A .001
A
.38
.020 x 45°
.375 DIA
.872 +.002 DIA.
ITEM 6
A
.878
.032
1.62
2.00
.375 DIA
.02 R
A .001
.032 x 45°
.015 x 45° (2)
.161 DIA. (NO. 20 DR.)
DEEP CTSK. TO .210
DIA. 10-32 TAP MIN.
ORIENT TAPPED HOLES
& SLOT AS SHOWN APROX.
1.125
1
2
3
4
5
6
7
8
.38
3.25
1.62
.87
1.75
.37
1.125
.31
.209 DIA. (NO. 4 DRILL)
CTBZ DIA. .19 DEEP (2)
DRILL (2)
CHANGES
A

1-11410



A-25



8	2	10-32 x 3/8	FIL. HD. MACH. SCREW
7	1	3/8 x 1 1/2 x 3 1/2 PLASTIC	NYLON
6	1	3/8 DIA. x 1/2 PLASTIC	NYLON
5	1	1 1/2 DIA. x 2 1/2	STAINLESS STEEL
4	1	1.0 DIA x 2.0	STAINLESS STEEL
3	1	8-32 x 1/4	R.H. MACH. SCR.
2	1	NO. 8 S.A.E.	STEEL WASHER
1	1	1 1/2 DIA. x 1/2 PLASTIC	NYLON

HARVEY ENGINEERING LABORATORIES

PIEZO CRYSTAL HOLDING FIXTURE

DWG NO. 1-11410

B

DEEP FREEZE DETONATION TEST							
TEST NO.	FUZE	DETONATOR	°F	WEIGHT OZ.	DROP IN.	ENERGY IN/OZ.	RESULTS
1	M562	M47	-320	12.8	$3\frac{1}{16}$	39.2	FIRED HIGH ORDER
2	M562	M47	-320	12.8	$3\frac{1}{16}$	39.2	FIRED HIGH ORDER
3	M562	M47	-320	6.9	$3\frac{1}{16}$	21.1	NO FIRE- FIRING PIN PENETRATED
							DETONATOR APPROX. .070
4	M562	M47	94	6.9	$3\frac{1}{16}$	21.1	FIRED HIGH ORDER
5	M524	M2 DELAY	-320	13.8	$2\frac{13}{16}$	38.8	FIRED
6	M524	T33E1	-320	6.9	$3\frac{1}{16}$	21.1	FIRED HIGH ORDER
7	M524	M2 DELAY	-297	16.0	$12\frac{1}{4}$	196.0	FIRED- SEE NOTE 2
8	M524	M2 DELAY & T34E1 LEAD	-292	16.0	$12\frac{1}{4}$	196.0	FIRED - SEE NOTE 3
9	M524	M2, T34E1 AND [illegible] BOOSTER	-292 APPROX.	16.0	$12\frac{1}{4}$	196.0	FIRED HIGH ORDER
10	M562	M 47	68			FUZE MECH.	FIRED HIGH ORDER SEE NOTE 4
11	M562	M47	-120			FUZE MECH.	FIRED HIGH ORDER
12	M562	M47, FLASH RELAY	-60			FUZE MECH.	FIRED HIGH ORDER
13	M562	M47, FLASH RELAY	-305			FUZE MECH.	FIRED HIGH ORDER (MECHANISM USED
							IN PREVIOUS TEST)

SEE NOTE 1

NOTES:

1- TESTS NO. 7, 8 & 9 WERE CONDUCTED WITH EXPLOSIVE ELEMENTS ASSEMBLED NORMALLY AND INITIATED BY DROPPING A WEIGHT ON THE STRIKER

2- EXPLOSION WAS NOT AUDIBLE ABOVE NOISE OF THE WEIGHT HITTING THE STRIKER BUT A SUDDEN RISE IN THE RECORDED TEMPERATURE & SUBSEQUENT DISASSEMBLY PROVED TIME OF FIRING

3- EXPLOSION WAS NOT AUDIBLE BUT THE THERMOCOUPLE WAS BROKEN WHICH PROVED THE TIME OF FIRING

4- FIRED AT AMBIENT TEMPERATURE TO COMPARE METAL EROSION OF ADJACENT PARTS WITH COMPARABLE DETONATION AT CRYOGENIC TEMP.

FIG. 4

DEEP FREEZE FUZE MECHANISM TEST

FUZE	°F. MIN.	OPERATING TEMP. °F.	CODE	RESULTS (MECHANISM OPERATED NORMALLY UNLESS NOTED)
M562	-298	-38		OPERATED, WHEN TIPPED, ABOVE OPERATING TEMP.
M562	-315	AMBIENT		OPERATED DURING DISASSEMBLY
M562	-315	-130		
M562	-315	-120		INTERMITTANT OPERATION
		-277		
M562	-315	-270		
M524	-315	-305		
		-215	⊗	
		-245	⊗	
M524	-315	-115		
M562	-320	-125	⊗	
		-200	⊗	
		-245	⊗	
		-320	⊗	
M562	-320	-170	⊗	
		-320	⊗	
M562	-315	-315	△	
		-315	△*	
		-315	△*	BALANCE STAFF PACKED WITH GREASE AFTER THIS OPERATION
	-320	-298	⊗	OPERATION FORCED BY MANIPULATING BALLANCE STAFF.
		-230	⊗	
		-320	⊗△	
M562	-315	-65		
		-315	△	
	-320	-320	⊗△	
M562	-315	-39		
		AMBIENT		OPERATED DURING DISASSEMBLY
	-320	-320	⊗△	
M562	-315	-74		
		-65		
M562	-315	-137		
		-72		
		-303		
M562	-315	-22		
		AMBIENT		

A

	-320	-320	⊗△	
M562	-315	-39		
		AMBIENT		OPERATED DURING DISASSEMBLY
	-320	-320	⊗△	
M562	-315	-74		
		-65		
M562	-315	-137		
		-72		
		-303		
M562	-315	-22		
		AMBIENT		
	-320	-320	⊗△	
M562	-315	-68		
		-315		
		-315		
	-320	-320	⊗△	
M524	-315	-127		
		-102		
		-127		
		-119		
M524	-320	-215	⊗	
		-245	⊗	
M524	-320	-230	⊗	
		-230	⊗	
M524	-320	-200	⊗	
		-305	⊗	
		-230	⊗	
		-215	⊗	
		-230	⊗	
M509	-320	-320	⊗	
M509	-320	-320	⊗	

CODE:

BLANK CODE AREA INDICATES FUZES WERE ASSEMBLED AS SHOWN ON FIGURES 1 OR 2 AND COOLED AS SHOWN ON FIGURE 3.

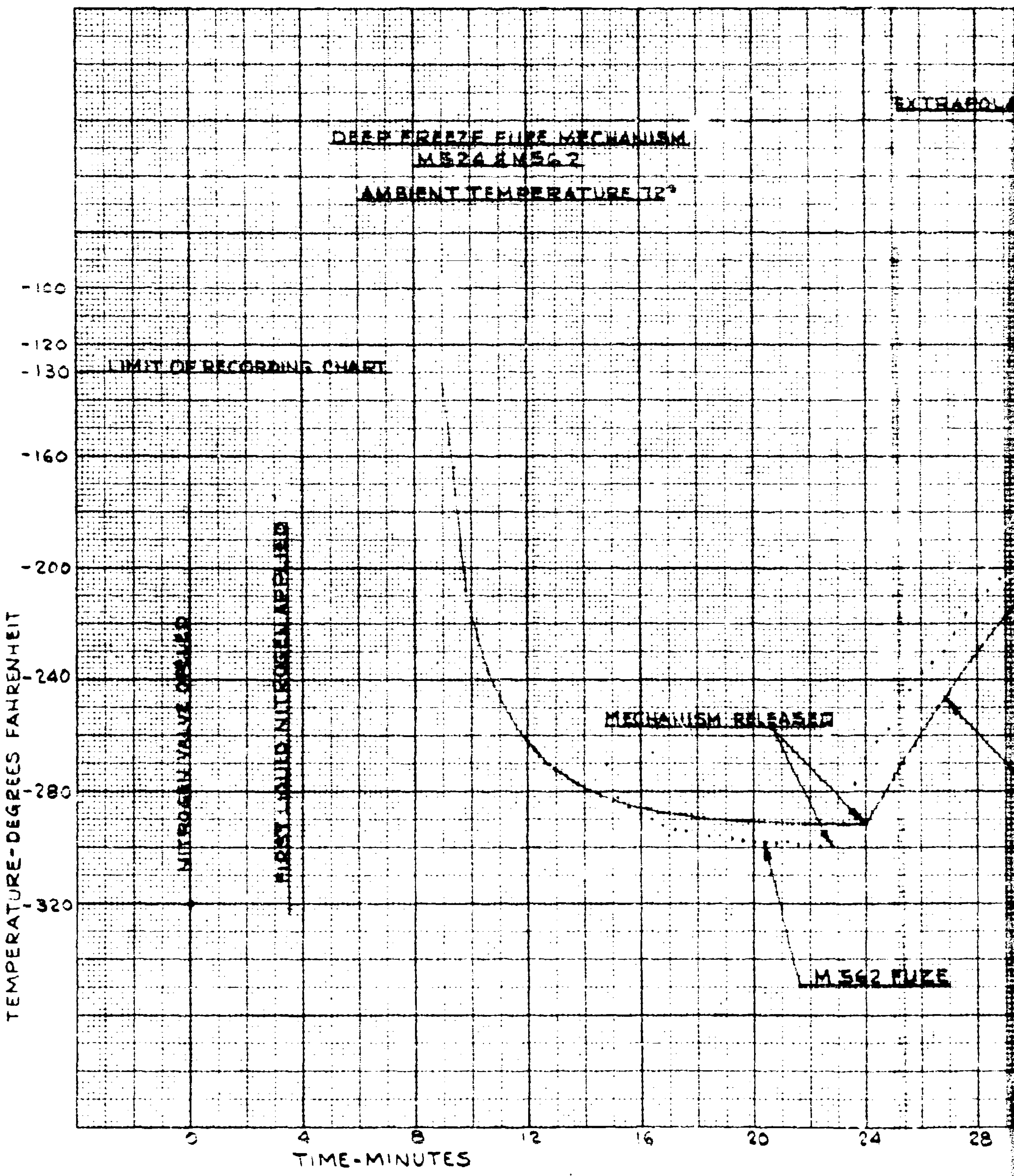
⊗ INDICATES FIRING OR ARMING MECHANISMS ONLY IMMERSED IN LN_2.

△ INDICATES FIRING PIN DID NOT ADVANCE (M562 FUZE ONLY)

* INDICATES MECHANISMS ASSEMBLED WITH BEARING PLATES AS FAR OUT OF LINE AS POSSIBLE.

FIG. 5

B


DEEP FREEZE FUZE MECHANISM
M524 & M562
AMBIENT TEMPERATURE 72°
LIMIT OF RECORDING CHART
NITROGEN VALVE OPENED
FIRST LIQUID NITROGEN APPLIED
MECHANISM RELEASED
M562 FUZE
TEMPERATURE-DEGREES FAHRENHEIT
-100
-120
-130
-160
-200
-240
-280
-320
TIME-MINUTES
0
4
8
12
16
20
24
28

A

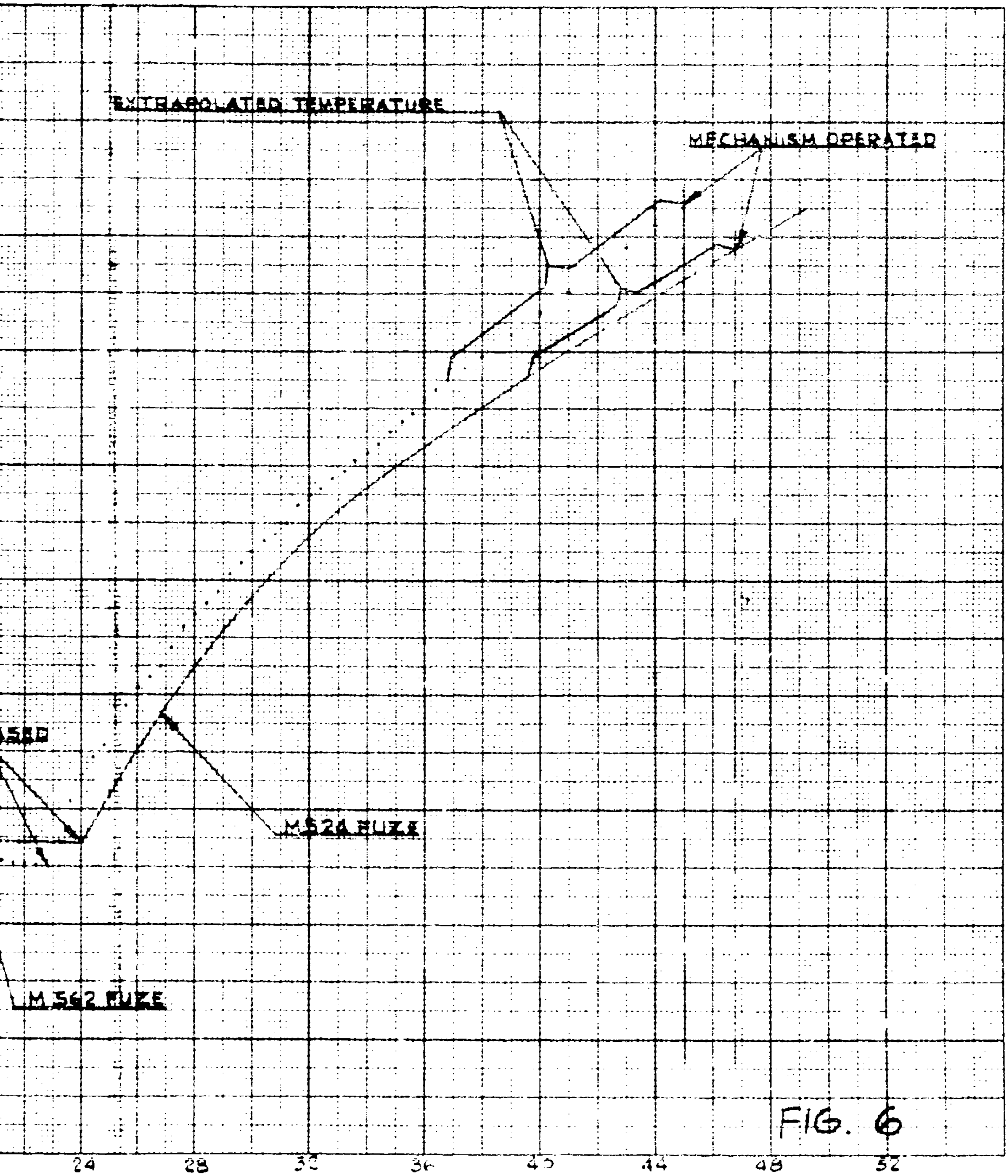

EXTRAPOLATED TEMPERATURE
MECHANISM OPERATED
M524 FUZE
M562 FUZE
24
28
44
48
52

FIG. 6

B